Trends in Snow Cover Frequency

Jim Coll Department of Geography and Atmospheric Science, University of Kansas Lawrence KS, 66045

Abstract

Despite its importance, trends of snow cover have yet to be qualitatively defined in any meaningful way, particularly at the global level. In this work, we attempt to quantify the magnitude and significance of snow cover frequency trends across the globe using more than 16 years of an improved and gap filled, MODIS daily snow cover dataset from 10/01/2000 through 10/01/2016. Across the High Plains Aquafer, large areas of increasing snow cover frequency are found in western Nebraska and eastern Colorado, and are neutral to decreasing across most of Kansas. The resulting maps depict a globally consistent and locally relevant snow cover assessment which may be used as a tool to help plan for future water needs, identify macro-, meso-, and micro- scale climatological effects and inform the public about this critical aspect of the hydrologic cycle.

Introduction

One of the most profound changes this planet experiences is the seasonal accumulation and ablation of snow cover. This cycle has far reaching effects not only on the biosphere, but also plays an integral role in our planets energy balance, climate, and hydrologic cycle. Snow cover has a much higher albedo as opposed to other types of land cover and plays an important role in global energy balances (1). As snow melts, it provides a source of potable water for as much as one-sixth of the world's population, significantly reducing the demands placed on alternative fresh water sources, both as an increase in surface water resources, as a source of recharge, and maintains basial flow rates for watersheds downstream (2, 3, 4). In addition, the winter tourism is a 12.2 billion dollar industry in the Unites States, and provides monetary benefits and jobs to 38 states (5).

However, little has been done to attempt to quantify the condition and trajectory of snow cover across the globe. Indeed, in the Fourth assessment Report of the Intergovernmental Panel on Climate Change, the strength of the snow albedo feedback estimates varied by a factor of three, mainly due to uncertainties in the location and state of the snow pack (6). This comes in a time when water resources are stretched thin, so maximizing the potential benefit of this is vital. Because snow cover provides so many ecological and social functions, it's vital to measure and track changes associated with it in order to better plan and prepare for the future. Furthermore, tracking changes at a global scale and at high resolutions creates a much clearer picture of the state of snow cover as opposed to smaller scale or coarser mapping efforts. Additionally, snow cover is sensitive to a variety of environmental forcers, and mapping its state and changes may shed light on patterns of climate change that were previously not discernable due to the limited scope of most snow cover studies. In this work, we present a global snow cover trend map using an improved daily snow cover dataset for the past 16 years (10/01/2000 – 10/01/2016), at a 500 m^2 resolution (7). This dataset, in conjunction with other surface parameters, can help further minimize the uncertainty in estimates of reservoir recharge rates, and identify areas of importance in both time and space.

Methods

Remote sensing of snow cover at any appreciable scale is complicated by myriad of factors, but by and large the greatest factor that inhibits the accurate detection of snow is cloud cover. Past research has shown that using the Fractional band of MOD10A1, using a no snow/snow threshold of 10, and a most recent clear observation filter of 7 days, which has an overall accuracy of ~85% To quantify snow cover, we will use snow cover frequency, defined as follows:

$$\text{Snow Cover Frequency} = \frac{\text{Number of Snow Cover Days}}{\text{Number of Days with Valid Observation}}$$

Snow cover frequency was calculated for every year from 10/01/2000 through 10/01/2016 (15 years), by year and for each month. To calculate the trend in snow cover frequency, Sens Slope was used. Sens slope is a nonparametric statistic used to estimate the slope of a linear trend, but makes no assumption as to the underling distribution of data, and is robust against outliers. It is defined as the median of all slopes $((Y_i - Y_j))/((X_i - X_j))$ for all points where j>i. This trend will be validated using 819 SNOTEL stations spread across the Western United States.

Results

MODIS generally underestimates snow cover. Comparisons to SNOTEL stations shows less agreement that desired, though the improved snow cover significantly increases the snow cover frequency calculation. This increased snow cover frequency accuracy reflect in a modest increase in the accuracy of both relative magnitude and direction of the trend.

Discussion & Conclusions

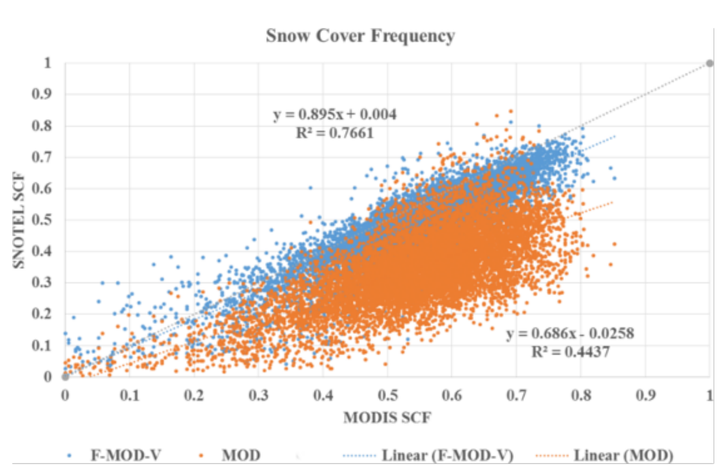
Due to a limited sample size (of two), we were unable to determine whether or not F-MOD-V, the modified dataset used, was able to accurately identify significant trends. However, the improved dataset was able to determine the direction and relative magnitude of trends at more than 70% of the stations. A web portal has been created so that users may view, explore, analyses, and download these data, the prototype of which can be seen here: https://code.earthengine.google.com/2e3df192299e74d6953e094a318f83bb. The results of this study, and related work can be found at globalsnowobservatory.com.

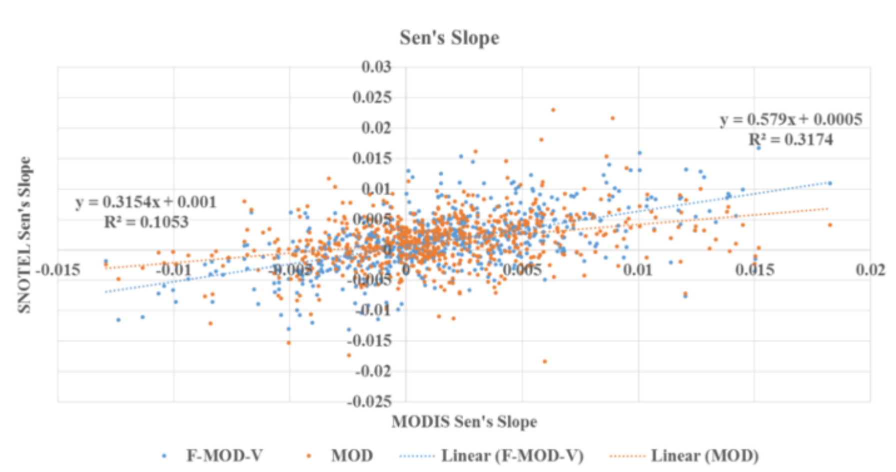
It is important to bear in mind that this is a trend in snow cover frequency, not snow water equivalents (SWE), and additional work needs to be done to help determine whether or not SWE is changeing. The various linkages and feedback loops snow cover has on surface and subsurface water resources are also not well quantified. More work needs to be done in order to understand this critical aspect of the hydrologic cycle if we are to accurately forecast and plan for the future of water in Kansas.

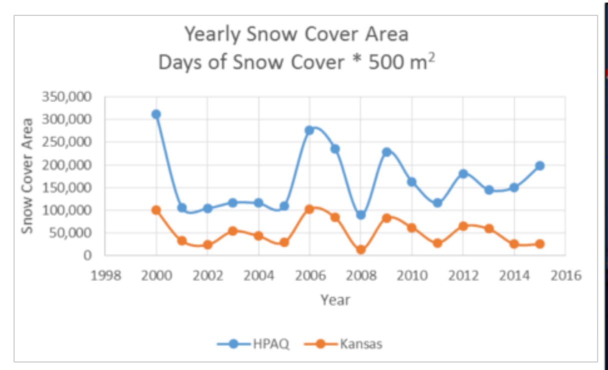
Sources

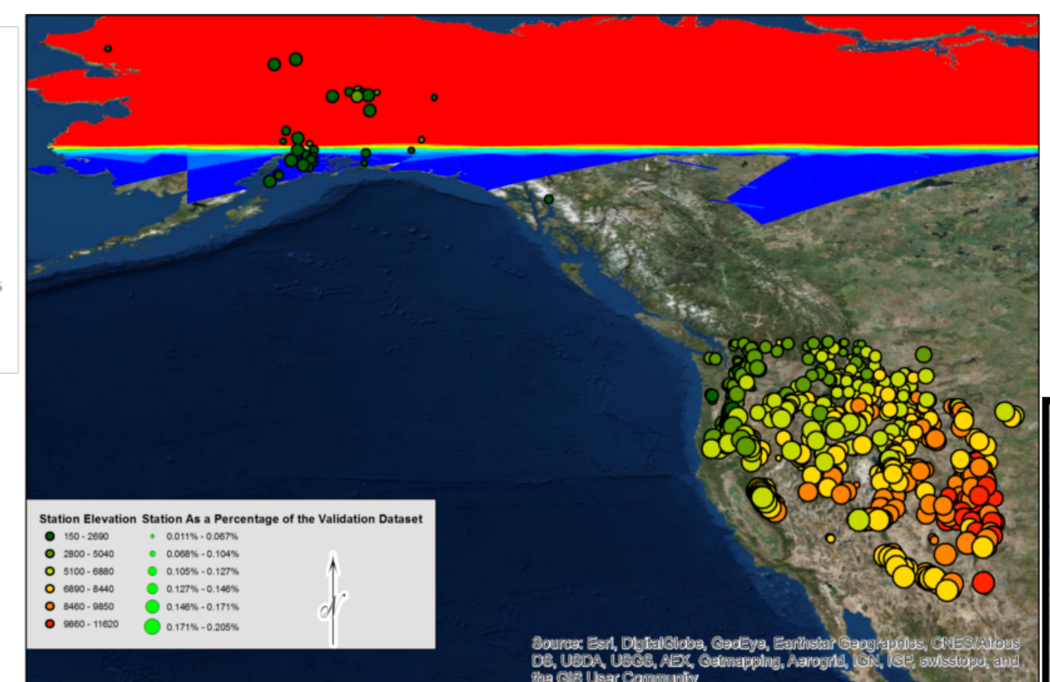
1 Earthobservatory.nasa.gov, (2015). Snow Cover & Net Radiation : Global Maps. [online] Available at: http://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD10C1_M_SNOW&d2=CERES_NETFLUX_M [Accessed 8 Dec. 2014]
2 Barnett, T., Adam, J., & Lettenmaier, D. (2005). Potential impacts of a warming climate on water availability in snow-dominated regions. Nature, 438(7066), 303-309. doi:10.1038/nature04141
3 Y. WuY. Xu, Snow impact on groundwater recharge in Table Mountain Group aquifer systems with a case study of the Kommissiekraal River catchment South Africa. Water SA. 31 (2007), doi:10.4314/wsa.v31i3.5207.
4 Viviroli, D., Dürr, H., Messerli, B., Meybeck, M., & Weingartner, R. (2007). Mountains of the world, water towers for humanity: Typology, mapping, and global significance. Water Resour. Res.,43(7), n/a-n/a. doi:10.1029/2006wr005653
5 Protect Our Winters (POW) and Natural Resources Defense Council (NRDC), (2012). Climate Impacts on the Winter Tourism Economy in the United States. [online] Available at: http://protectourwinters.org/climate_report/report.pdf [Accessed 27 Jan. 20
6 K. Rittger, T. Painter, J. Dozier, Advances in Water Resources, in press, doi:10.1016/j.advwatres.2012.03.002.
7 J Coll, X. Li, Comprehensive Accuracy Assessment of MODIS Daily Snow Cover Products and Gap Filling Methods, in review

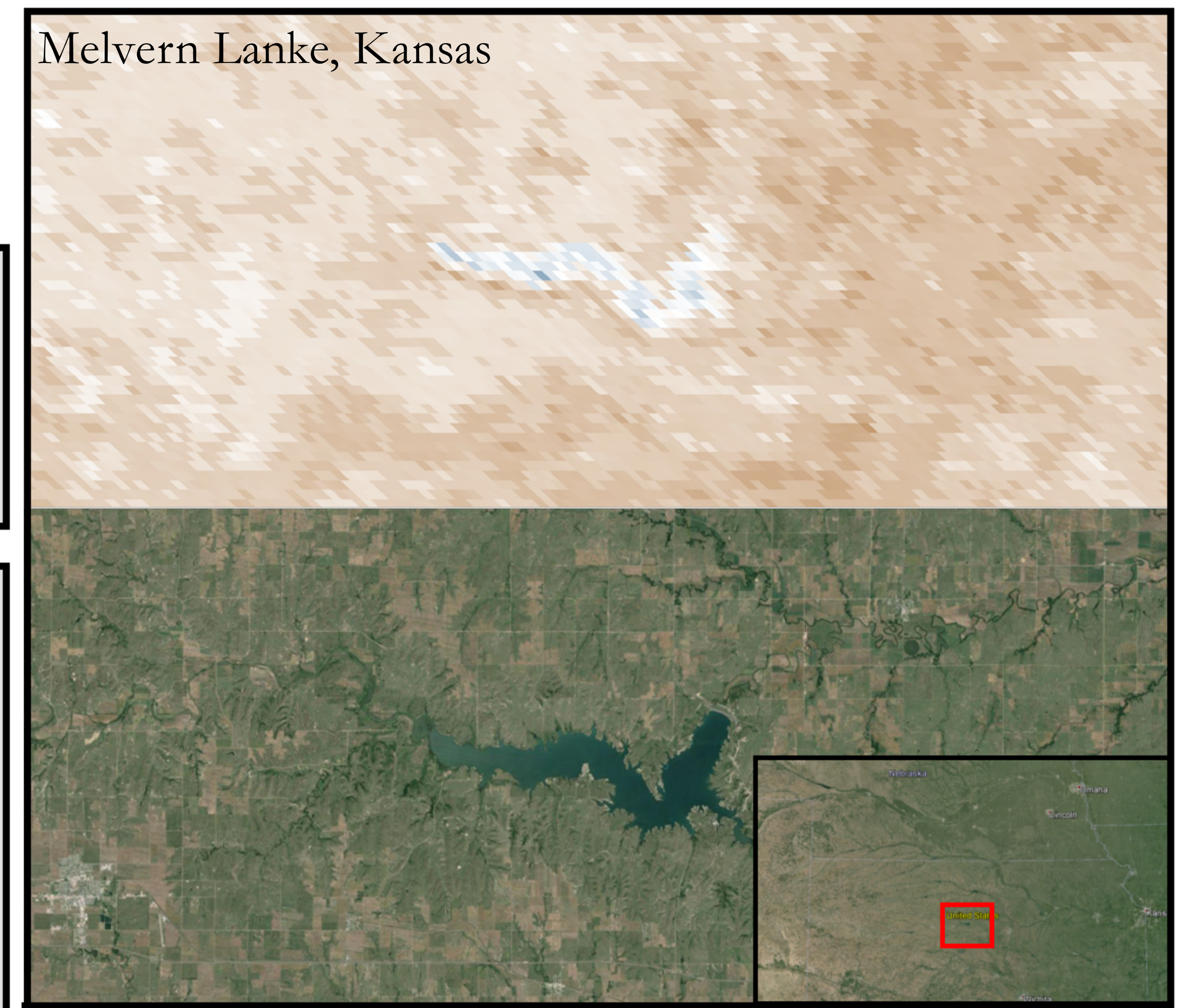
This work was performed with both financial and resource support from Google Earth Engine.

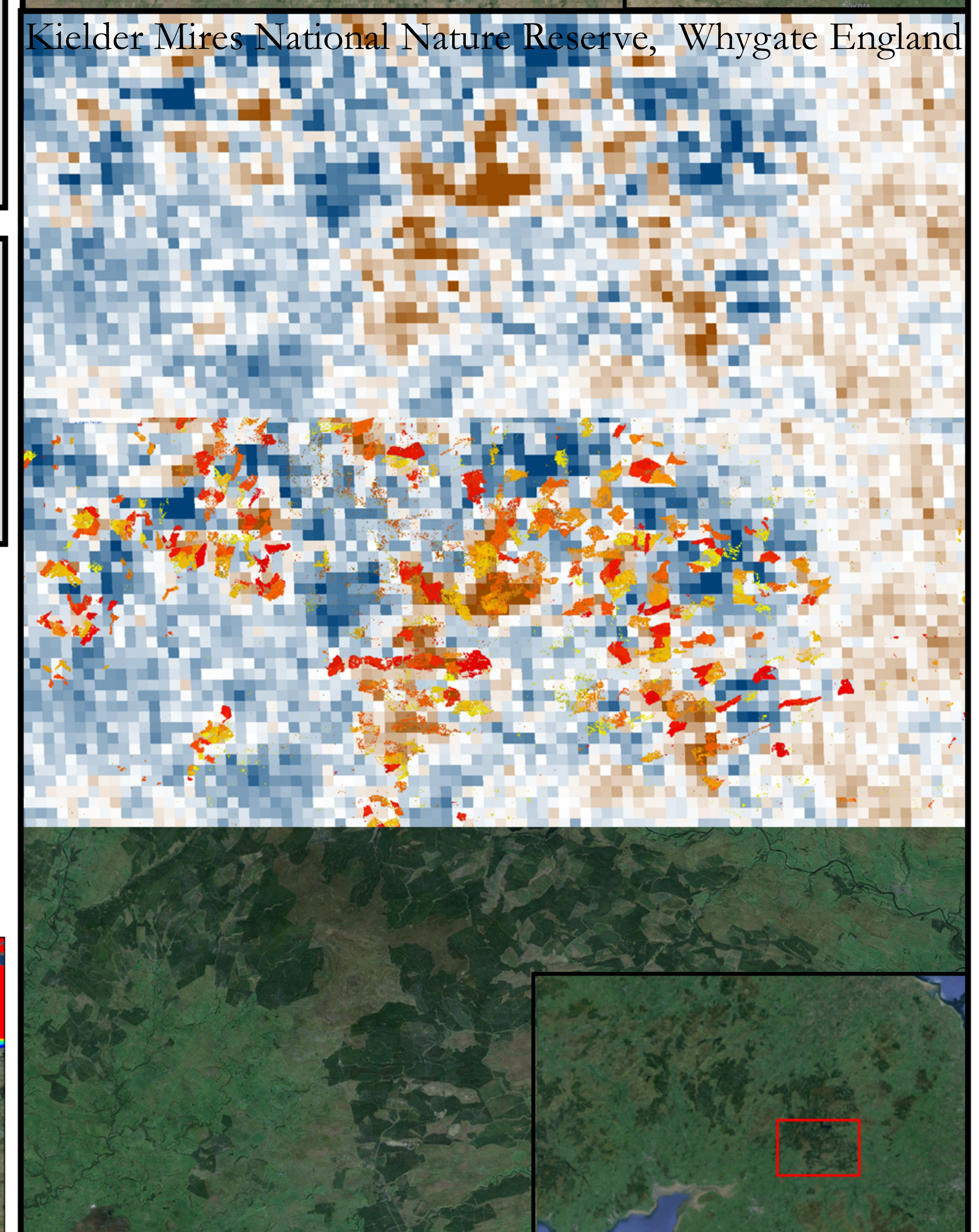


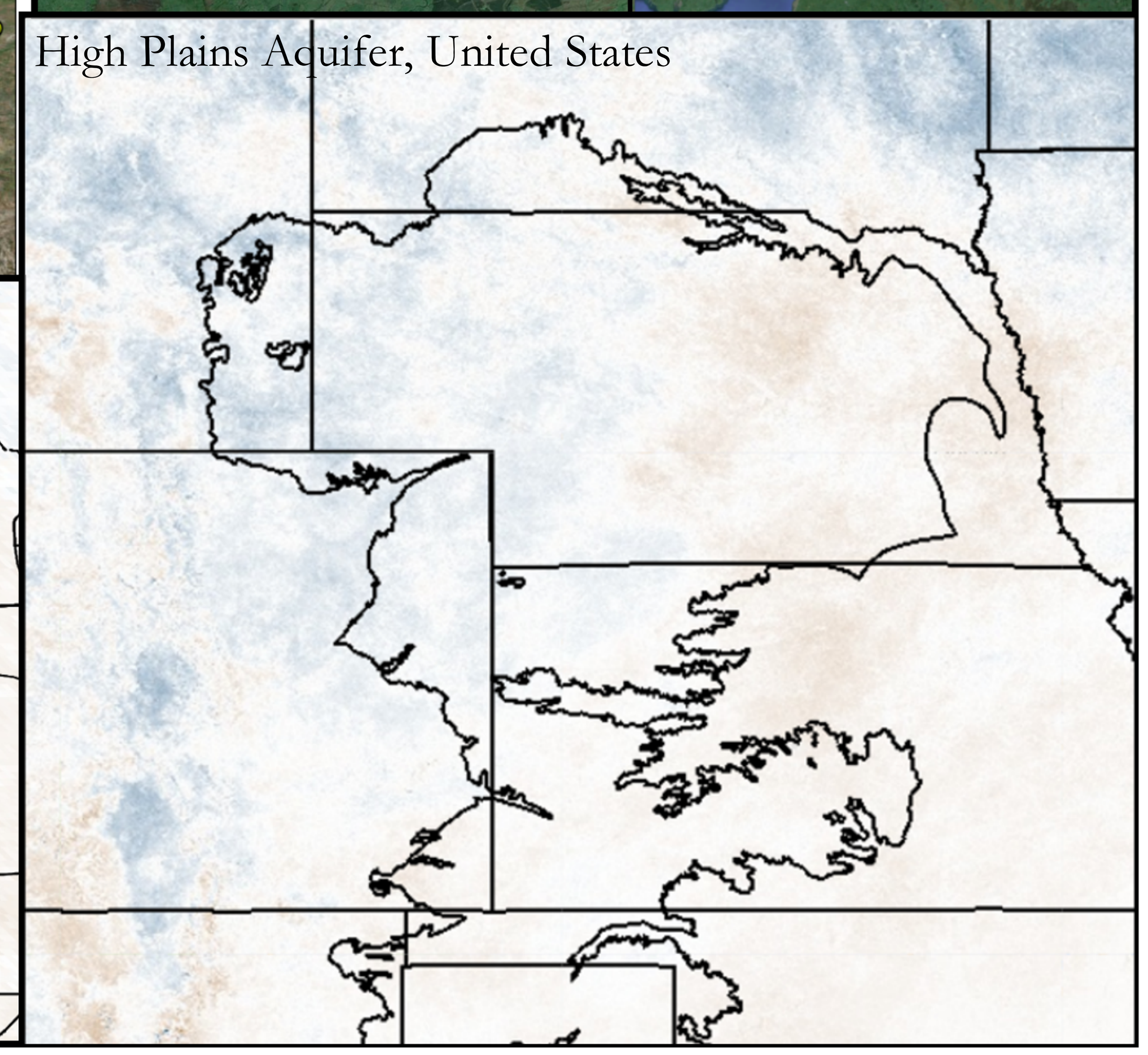


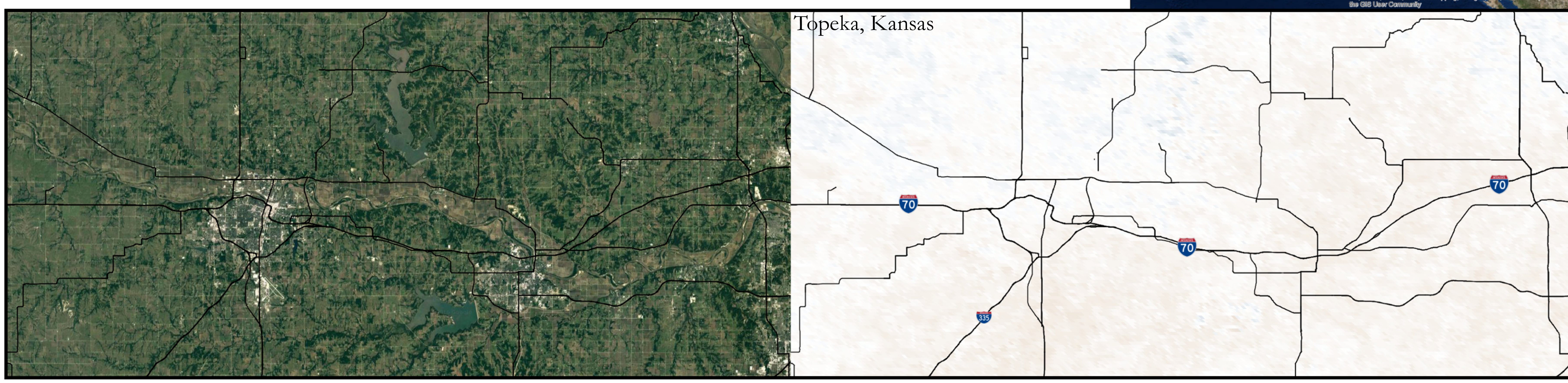





Melvern Lanke, Kansas


Kielder Mires National Nature Reserve, Whygate England


High Plains Aquifer, United States


Topeka, Kansas